

CS422 Assignment 2

Sharvil Sachin Athaley (210961)
Samyak Singhanian (210917)
Sanath Salampuriah (210919)

March 25, 2025

Introduction

This report presents the results of experiments conducted to evaluate the performance of different branch direction predictors and branch target buffers (BTBs) for a set of benchmark programs.

Note : GAg and SAg predictors used in the meta predictors are separate structures.

1 400.perlbench

1.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 130119265

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.378225	0.562225	0.414826
Bimodal	0.0975355	0.0806159	0.0941699
SAg	0.0369185	0.0333382	0.0362063
GAg	0.123417	0.0899843	0.116766
gshare	0.100189	0.0969295	0.0995409
Combined2	0.0316602	0.0272466	0.0307822
Combined3Majority	0.0500811	0.0473017	0.0495282
Combined3	0.0288315	0.0233117	0.0277335

1.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 28140228

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	0.000159771	0.344966
BTB2	0.0180569	0.104572

1.3 Observations and Analysis

1.3.1 Part A: Direction Predictors

1. Static predictor is the worst among all as it does not learn anything over time nor does it store history.
2. Bimodal predictor performs better than static but worse than most of the others. Although it does learn over time, it is not as sophisticated as the other predictors.

3. SAg performs better than GAg, as SAg stores and learns the history of individual branches, rather than a global history and captures local patterns.
4. gshare performs better than GAg but worse than SAg. gshare performs better than GAg as it tries to combine GAg with some branch specific indexing but does not maintain a local history like SAg.
5. The combined predictors generally have better accuracy. SAg captures local behaviour of branches but does not capture global correlation like GAg does. The hybrid predictors combine both these things and hence work better.
6. **Best Predictor:** Combined3 Predictor.

1.3.2 Part B: Branch Target Buffers

1. Such high percentages of misses and mispredictions might be due to many indirect calls that go to different target addresses every time.
2. BTB indexed with a hash of PC & global history register performs better than the other. The reason could be that a large number of indirect calls cause frequent replacements. The second way of indexing can improve that.

2 401.bzip2

2.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 129923129

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.309892	0.619445	0.46892
Bimodal	0.107903	0.0924878	0.0999839
SAg	0.114242	0.0892617	0.101409
GAg	0.147518	0.10389	0.125105
gshare	0.121152	0.105467	0.113094
Combined2	0.108431	0.0838973	0.0958274
Combined3Majority	0.10201	0.0845028	0.0930162
Combined3	0.100769	0.0821717	0.0912149

2.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 791928

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	7.45017e-05	0.482938
BTB2	0.000270227	0.475236

2.3 Observations and Analysis

2.3.1 Part A: Direction Predictors

1. Observations are exactly as in 400.perlbench
2. **Best Predictor:** Combined3 Predictor.

2.3.2 Part B: Branch Target Buffers

1. Observations are same as in 400.perlbench

3 403.gcc

3.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 133795012

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.316153	0.046387	0.106511
Bimodal	0.125643	0.0204449	0.0438909
SAg	0.0774177	0.0135938	0.0278186
GAg	0.119923	0.0191338	0.0415973
gshare	0.118505	0.017524	0.0400303
Combined2	0.0589128	0.0105907	0.0213605
Combined3Majority	0.071855	0.0126427	0.0258397
Combined3	0.0526926	0.00977342	0.0193391

3.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 7129129

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	6.67683e-05	0.352484
BTB2	0.00962684	0.121809

3.3 Observations and Analysis

3.3.1 Part A: Direction Predictors

1. Observations are exactly as in 400.perlbench
2. **Best Predictor:** Combined3 Predictor.

3.3.2 Part B: Branch Target Buffers

1. Observations are same as in 400.perlbench

4 429.mcf

4.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 178242886

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.357086	0.2819	0.319495
Bimodal	0.162872	0.197519	0.180195
SAg	0.150972	0.11002	0.130497
GAg	0.0922693	0.0934404	0.0928548
gshare	0.103475	0.100909	0.102192
Combined2	0.0894928	0.0860087	0.0877508
Combined3Majority	0.0876034	0.0860207	0.0868121
Combined3	0.0854488	0.0826108	0.0840299

4.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 12556567

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	7.16756e-07	0.0061348
BTB2	8.36216e-06	0.00409937

4.3 Observations and Analysis

4.3.1 Part A: Direction Predictors

1. Observations are exactly as in 400.perlbench
2. **Best Predictor:** Combined3 Predictor.

4.3.2 Part B: Branch Target Buffers

1. Observations are same as in 400.perlbench

5 450.soplex

5.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 103135120

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.200388	0.157204	0.171420
Bimodal	0.0099632	0.0675866	0.0486166
SAg	0.0074822	0.0570147	0.0407083
GAg	0.0097376	0.0531750	0.0388751
gshare	0.0143107	0.0535357	0.0406226
Combined2	0.0073956	0.0506974	0.0364422
Combined3Majority	0.0091557	0.0529527	0.0385344
Combined3	0.0073919	0.0506846	0.0364323

5.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 6333664

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	1.87885e-05	0.00024725
BTB2	8.16273e-05	0.00032430

5.3 Observations and Analysis

5.3.1 Part A: Direction Predictors

1. Observations are exactly as in 400.perlbench
2. All predictors perform relatively better on this benchmark.
3. **Best Predictor:** Combined3 Predictor.

5.3.2 Part B: Branch Target Buffers

1. Observations are same as in 400.perlbench
2. All predictors perform relatively better on this benchmark.

6 456.hmm

6.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 144361243

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.766308	0.00669727	0.639141
Bimodal	0.102042	0.00353682	0.0855509
SAG	0.108636	0.00480272	0.0912532
GAG	0.136184	0.025661	0.117681
gshare	0.117955	0.0270597	0.102738
Combined2	0.102257	0.00771069	0.0864288
Combined3Majority	0.103097	0.00625656	0.0868851
Combined3	0.0994756	0.00417337	0.0835209

6.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 201471

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	0.000317664	0.0635824
BTB2	0.00362335	0.02583

6.3 Observations and Analysis

6.3.1 Part A: Direction Predictors

1. Observations are almost as in 400.perlbench. However the combined predictors other than combined3 do not perform as well as in other benchmarks.
2. All predictors perform relatively better on this benchmark.
3. **Best Predictor:** Combined3 Predictor.

6.3.2 Part B: Branch Target Buffers

1. Observations are same as in 400.perlbench
2. All predictors perform relatively better on this benchmark.

7 471.omnetpp

7.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 117334361

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.337249	0.361839	0.341219
Bimodal	0.0972794	0.138895	0.103999
SAg	0.0436215	0.0833156	0.0500305
GAg	0.118268	0.143421	0.122329
gshare	0.103793	0.132551	0.108436
Combined2	0.0358435	0.0689807	0.0411938
Combined3Majority	0.0476378	0.0922593	0.0548425
Combined3	0.0338331	0.065853	0.0390031

7.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 30294880

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	0.000261727	0.293709
BTB2	0.010681	0.118411

7.3 Observations and Analysis

7.3.1 Part A: Direction Predictors

1. Observations are same as in 400.perlbench.
2. **Best Predictor:** Combined3 Predictor.

7.3.2 Part B: Branch Target Buffers

1. Observations are same as in 400.perlbench

8 483.xalancbmk

8.1 Part A: Direction Predictors Analysis

Total count of conditional branches : 191229971

Predictor	Forward Misprediction	Backward Misprediction	Overall Misprediction
Static	0.0742012	0.0446599	0.0669763
Bimodal	0.0346187	0.0187119	0.0307284
SAg	0.0183609	0.0104652	0.0164299
GAg	0.0434420	0.0278485	0.0396283
gshare	0.0374423	0.0262362	0.0347016
Combined2	0.0136197	0.00919155	0.0125367
Combined3Majority	0.0203408	0.0146124	0.0189398
Combined3	0.0126457	0.00811489	0.0115376

8.2 Part B: Branch Target Buffers Analysis

Total count of indirect calls : 30825826

BTB Predictor	BTB Miss Rate	Misprediction Fraction
BTB1	0.0225886	0.260335
BTB2	0.154722	0.273685

8.3 Observations and Analysis

8.3.1 Part A: Direction Predictors

1. Observations are same as in 400.perlbench. All the predictors performed relatively well on this benchmark.
2. **Best Predictor:** Combined3 Predictor.

8.3.2 Part B: Branch Target Buffers

1. The second BTB (the one indexed with hash of GHR and PC) performs slightly worse on this benchmark.